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# Case Study on Cold Air Distribution of a Data Centre

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***Abstract* - Every organisation needs to use modern technology to efficiently manage all its functions encompassing procurement; inventory control; design, production planning and control; manufacturing; transport and shipping; human resources; marketing and sales etc. To perform these functions, Information and Communication Technology (ICT) is adopted as integrated package. Hardware, software and supporting infrastructure is housed in a building called Data Centre (DC).**

*Keywords – Data Centre, Cold Air Distribution, CRAC, IT Room, Thermal Modelling, CFD.*

## I. INTRODUCTION

A Data Centre is a facility housing Information Technology (IT) racks; Software to manage input, output, manipulation and receipt/ transmission of data using communication network; Power and Emergency power back up; Uninterrupted Power Supply (UPS) for improving power quality and availability; Air Conditioning (AC) to regulate IT room ambience; Fire detection, Fire fighting system and Security system; Lighting and miscellaneous building infrastructure.

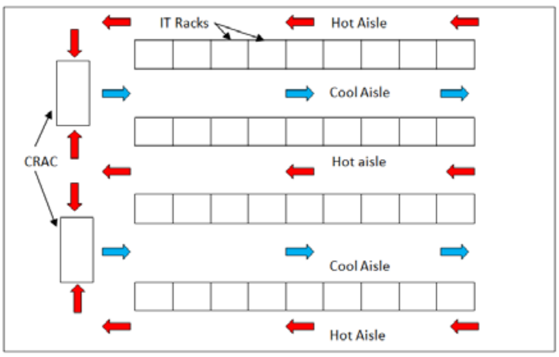


*Fig. 1.1- A typical data centre room*

A typical data centre with IT racks and Computer Room Air Conditioning (CRAC) unit is shown in Figure 1.1.

IT equipment architecture varies based on requirements of computing and storage. Air conditioning is a dependent variable with IT rack power density and relative position in the data centre room. Placement of racks and CRAC can be planned based on available room space and provision for future expansion. Cold air from CRAC can reach IT racks directly, through false floor or through overhead room duct. Similarly, Hot air can be collected by CRAC units directly: through false ceiling or through overhead room duct. Any combination among six methods can be adopted.

## II. LITERATURE REVIEW

Good amount of research work has been done on Air distribution strategies to improve it and to reduce energy consumption.

**Neil Rasmussen** compared air distribution methods on cool air and hot air sides. Cold air can discharge into the DC room directly, using cold air duct or false floor. Hot air after cooling IT rack and surrounding room can return to the CRAC directly, through false ceiling or through hot air duct collecting hot air from IT rack and delivering to the CRAC. Combination of above variables gives different configurations. Use of hot and cold air duct facilitates meeting average load of the room. This is also suitable for IT racks with higher power density [1].

**Paul Lin Victor Avelar & John Niemann** researched into existing DC. False ceiling for taking hot air and false floor for cold air was recommended for better efficiency. Provision of

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overhead ducts, for cold or hot air in a working DC, pose problem in operations. For specific requirement other methods can be used [2].

**Kevin Dunlap and Neil Rasmussen** examined different types of IT racks in the industry for comparing different air distribution methods suitable for them. First type is room based cooling as shown in Figure 1.1. Cold and hot air do not use duct or false floor/false ceiling. In this cold and hot air paths are longer and there is likelihood of air mixing. Both situations lead to inefficiency. Second type is row based cooling [Figure 1.2]. AC unit is located as part of the IT rack rows at number of locations. Cold air is discharged in front and hot air is collected from rear. Air paths are short and air mixing opportunity is minimum. They are

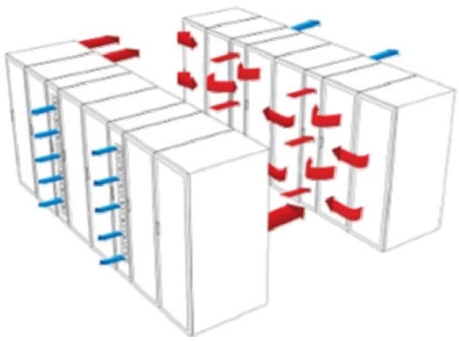

*Fig. 1.2- Floor-mounted row-based cooling [3]*

more efficient compared to the first type. Third type is called rack based cooling system. In this cooling unit is part of the individual rack. This provides least paths for cold and hot air with no chance of air mixing. Among three types this type is most efficient. Planning is required with IT manufacturer for providing second and third types of arrangement. First type is recommended for low power density IT rack installations. When power consumed by IT rack increases, second type give better performance. For extremely high power density IT racks, third type is only suitable [3].

**John Bean & Kevin Dunlap** studied performance of chilled water air conditioning system with compressor and condenser units located outdoors and air handling (AH) units indoors. Within room, AH unit can be located at one place called Central Air Handling Unit (CAHU). It can be located at different locations around internal perimeter of the room called Computer Room Air Handler (CRAH). It can also be located in alignment with IT racks called In Row Air Handler (IRAH). In their study, authors found CAHU, CRAH, and IRAH to be efficient in increasing order respectively [4].

**James W. Van Gilder & Roger R. Schmidt** made study on the installations in which cold air is discharged to the inner side of the perforated tiles. These tiles are placed over the real floor and serve as a plenum space for cold air. Through perforations/grilles, the cold air is sent to the IT rack bottom. They come out from top of the rack after picking heat of the rack. Grilles are also provided to cool balance space of DC room. After study it is recommended that tile with 25% opening is better than with 56% openings. Design plenums for clear airflow space of 0.61 m (24 in) or more. Minimise leakage airflow through non-perforated tile openings in the raised floor [5].

**Neil Rasmussen** studied concept of false floor for use as cold air plenum. There is trend in IT industry to provide more and more electronics in a rack for reducing its footprint and building more capacity. As a consequence, energy intensity per rack is rising so is volume of cold air for extracting heat from the rack. For DC room populated with such racks, false floor height beyond 1 m is required. Power and communication cables, earthing wires, and sometimes chilled water piping also are put in the false floor, thereby reducing air space for cold air. Fire safety requirement is made stringent if power cable is run under false floor. False floor also weakens earth quake resistance of the structure. A recommendation is to avoid false floor for cold air distribution. Use of overhead duct for cold air and cable trays for power/ chilled water piping are preferred [6].

**Jetsadaporn Priyadumkol & Chawalit Kittichaikarn** researched on perimeter based CRAC air distribution using false floor and found cooling at top portion of the rack inadequate although at lower levels it was satisfactory. Field measurement was validated through CFD analysis. They suggested use of Inline AC units in combination with perimeter CRAC to cool racks at all levels [7].

**Zhihang Song, Bruce T. Murray, Bahgat Sammakia** proposed the development of a velocity propagation method (VPM) based dynamic compact zonal model to efficiently describe the airflow and temperature patterns in a data centre with a contained cold aisle. The results were compared with those using full CFD simulations and results were satisfactory. Full scale data centre thermal modelling and optimisation using computational fluid dynamics (CFD) is generally an extremely time consuming process [8].

**Neil Rasmussen** describes cooling strategies for Ultra-High Density Racks. Author proposed differential cooling strategy. Air distributions are planned for average energy racks while supplemental cooling is provided for high density

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racks. If required, high energy intensity IT racks can be located together cooled with additional ducting [9].

## III. RESEARCH GAP

Due to severe hot and humid conditions, cold air requirement is large in India. Power quality and availability is also poor, requiring more cold air distribution capacity to meet no power situation. Various studies on air distribution arrangements for DC are conducted abroad. There is a need to conduct more study for Indian set up to evaluate and get benefit from previous studies. Present paper fills up this gap.

## IV. OBJECTIVE

Data centres are security installations for owners/operators. Access for carrying study is difficult. With cooperation from authorities, permission to carry out limited study in one of the existing data centre was obtained. As a result, a case study was done in a Data Centre owned and operated by a central public sector unit at Bhopal.

## V. METHODOLOGY

To undertake study, following steps were taken

- To prepare the actual drawing showing room measurement, IT rack, CRAC and supply air grilles in false floor.
- To study air flow balance from and to CRAC
- To study air bypassing false floor
- To study air flow through false floor related to obstruction and efficiency

The room measures 12.78 m x 8.75 m x 4.25 m height. Floor plan of DC room is shown in Figure 5.1.

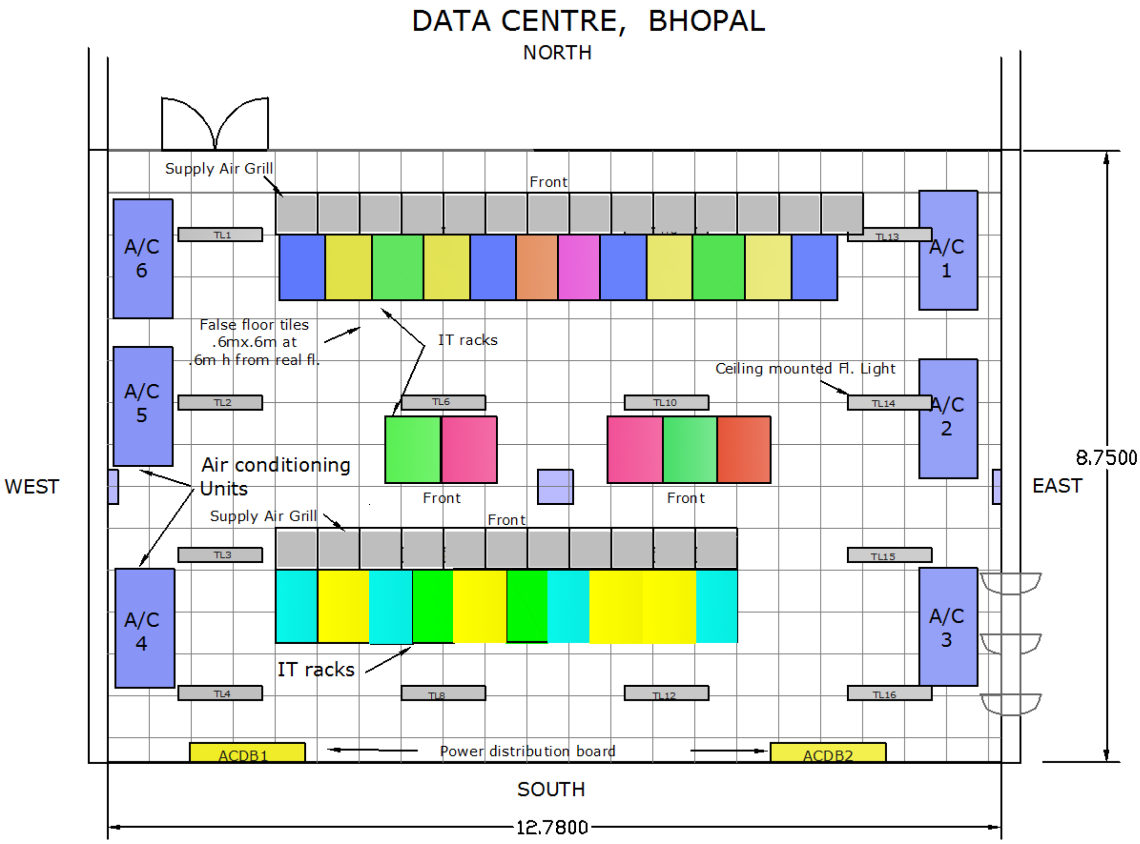


*Fig. 5.1- Floor plan of showing equipments*

To meet cooling load of IT racks and room conditions CRAC units discharge cool air to false floor and through it to the bottom of IT racks. The cool air picks up heat from racks while passing vertically inside and exiting from top. Some racks are not designed for this arrangement. They are cooled by supply air grilles provided at salient points in false floor. Total 6 numbers of CRAC units are in use (includes 2 units as stand by) to meet heat load of the room with inside design conditions of 23°C and relative humidity of 50% as per ASHRAE recommendations.

### Deficiency in Air distribution system

It was observed that cold air is leaking through openings in partition wall between room and power room on south side, through doors and windows. False floor is used for directing cold air to reach IT

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rack. Some of the air was coming out of cable cut outs provided in the false floor and through joints in the false floor.

### A. Air balance between supply and return to CRAC

The measurement is given below. The difference of 3.40 m3/minute is very small and seems to be due to measurement error.

| | |
|---|---|
| Total Discharge from 4 units, m3/minute | 1335.09 |
| Total return air to 4 units, m3/minute | 1323.18 |
| Through leakage to Power room m3/minute | 8.51 |
| Total | 1331.69 |
| Difference | 3.40 |

### B. Supply air balance through false floor supply air grilles

| | |
|---|---|
| **A. Input** | |
| Discharge from 4 units, m3/minute | 1335.09 |
| **B. Output** | |
| 1 Through SA grills, m3/minute | 708.74 |
| 2.Through cable cut outs, m3/minute | 70.46 |
| 3.Through leakage to Power room | 8.51 |
| 4.Through cut out below ACDB1 &2 | 19.75 |
| Sub total | 807.46 |
| **C. (A-B):Balance** , m3/minute | 527.62 |

Thus cool air bypassing racks was staggering 527.62 m3/minute (1335.09-807.46) equivalent to 39.52%.

### C. Energy Loss due to cold air escaping to Power room

| | |
|---|---|
| 1 Leakage to Power room m3/minute | 8.51 |
| 2 Average loss per unit for 4 units[R1/4], m3/minute | 2.1275 |
| 3 Cooling loss, W =20.4x2.1275x( 41.1-23) | 785.5581 |
| 4 Energy loss, kW= Cooling loss/(COP 3.3x1000) | 0.23804790 9 |
| 5 Annual loss [R4x24x365], kWh | 2085.3 |

### Pressure loss in absence of bends at A/C outlets

During case study it was observed that the flow of cool air from bottom of the blower of AC unit is directed vertically downwards inside false floor. After rebounds, it was finally taking horizontal direction. The air has no smooth passage to divert through $90^o$ to travel to the supply air grills. This results into loss of pressure and therefore energy. A $90^o$ bend will smoothly guide the air flow, as shown in the Figure 5.2. Average velocity of cool air is measured as 12.29 m/s at the outlet of the blower. The benefit of providing a 90 deg bend is to save power of 132 watt as analysed in Table 5.1. It is recommended that all Bottom feed AC machines be provided with suitable bends to direct cool air smoothly in the desired direction to prevent energy loss.

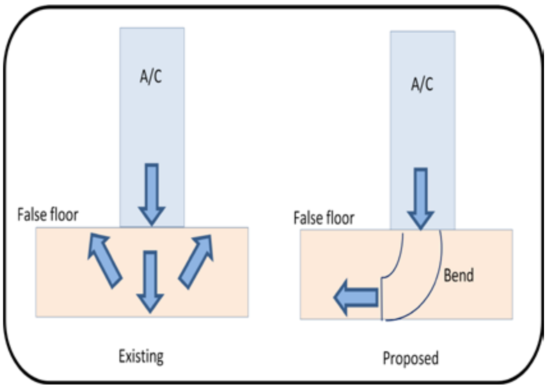


*Fig. 5.2: Provision of bend at A/C discharge outlet*

| |
|---|
| As per ASHRAE hand book, pressure loss $\Delta p_V$ for 90 degree turn: |
| Loss for 180 degree bend =180/90 = 2 |
| Thus additional loss in 180 deg bend compared to 90 deg bend = |
| : Loss due to 90 degree bend as worked out below- |
| Average velocity C = 12.29 m/s, Supply air duct dimension: 0.365x0.62 |
| Velocity pressure head , N/m$^2$ = $p_V = \rho C^2/2$ =1.2x 12.29$^2$/2 = 90.18 |
| Discharge duct aspect ratio = Longer dim/Shorter dim = 0.62/0.365 = 1.7 |
| Dynamic loss coefficient K = .22-(.22- .19)x(1.7 - 1)/(4 - 1) = 0.213 |
| $\Delta p_D$ = K x $p_V$ = 0.213x90.18 = 19.2 N/m$^2$ |
| Discharge from 1A/C units, m$^3$/sec =1323.18/(60x4) =5.513 |
| Loss of power, W assuming 80% fan efficiency =19.2x5.513/.80 =132.31 |
| Annual energy loss, kWh, with 21900 machine hours |
| 132.31x21900/1000 =2098 kWh |

*Table 5.1 Savings in power with a provision of $90^o$ bend at A/C discharge outlet*

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## VI. CONCLUSIONS, RECOMMENDATIONS AND FUTURE SCOPE

The literature review lists opportunities to improve air distribution in a Data Centre. Suggestions with respect to type of IT racks and avoiding false flooring can be implemented only in new installation. In existing installation, study was restricted to evaluate air distribution using false floor. Following conclusions and recommendations are for this existing installation:

- Any cold air loss is loss of revenue. It needs to be plugged. Cold air loss to power room can be completely eliminated
- Sealing of windows and doors can eliminate/reduce cold air losses
- To reduce pressure loss at the outlet of AC unit at false floor level, a 90 degree bend can smoothly guide air stream within false floor.

For new installations:

- Avoid false floor and use cold air duct to improve air distribution effectiveness
- In consultation with IT rack manufacturer plan for row or in line cooling

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